

Short Communication

Synthesis of Ordered Mesoporous Carbon and Its Electrochemical Performances

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Using the polyethylene-polypropylene glycol (F127) as raw material, ordered mesoporous carbon (OMC) was synthesized by the template method. The structure and morphology showed that the ordered mesoporous carbon had orderly rules and the width of wall was 10 nm. Constant current charge and discharge, cyclic voltammetry and impedance spectra showed that this electrode materials with good electrochemical performance, good reversibility. At a current density of 700 mA/g, ordered mesoporous carbon had capacitance retention rate of 90.5% after 500 cycles test.

Keywords: template, ordered mesoporous carbon, electrochemical

1. INTRODUCTION

Supercapacitors offer a promising alternative approach to meeting the increasing power demands of energy storage system in general [1-3]. Supercapacitors currently fill the gap between batteries and conventional solid state and electrolytic capacitors [4-6]. Supercapacitors have been widely recognized as a unique electrochemical device which is designed to possess high specific energy and power density [7-9].

For many years, carbon has been the electrode material of choice for supercapacitors because it conducts electricity, is light, and can be formed into a meshlike structure that sops up ions like sponge[10-12]. Since the first report in 1999, ordered mesoporous carbons (OMCs) have received considerable attention because of their unique structural features and many promising applications. Nanocast ordered mesoporous carbons (OMCs) are particularly interesting as electrode materials for supercapacitors in terms of both fundamental research and practical application [2, 13-15].

A number of currently studied electrode materials are based on the carbon materials above. The materials demonstrate significant electrochemical activity; however, the outstanding electrochemical

properties and unique charge transfer channel of ordered mesoporous carbon (OMC) make them the most promising candidate for electronic applications.

2. EXPERIMENTAL

2.1 Materials preparation

All the chemicals were of analytical reagent and used as received without further purification. OMC is synthesized with a simple modified one-pot chemical method. First, add 2.5 g polyethylene-polypropylene glycol (F127) to a solution containing 10 mL water and 10 mL ethanol, stir for 30 min. Then add 1.6 g resorcinol and 0.2 g HCl (37 wt%) to the solution. Stir for 1 h until the solution became light yellow color. Next, add 2.4 g formaldehyde (37 wt%) to the solution and let the solution stand in the dark for five days until it separated into two layers. After discarding the upper layer, the under layer was cured at 90 °C for three days until it turned into an ivory gel. Then, the ivory gel was thermally decomposed at 800 °C at ramping rate of 2 °C min⁻¹ in N₂ for 3 h, and a well-ordered mesoporous carbon was obtained.

2.2 Materials characterization

OMC materials were characterized by X-ray diffraction (XRD), scanning electron microscopy and transmission electron microscopy. Powder x-ray diffraction (XRD) patterns of the sample was recorded on a Philips X'pert diffractometer with Cu K α radiation ($\lambda=1.5418$ Å). The morphology and the structure of the sample were examined with a field-emission scanning electron microscopy (FESEM, JEOL JSM-6300F) and transmission electron microscopy (Tecnai G² Spirit).

2.3 Electrochemical measurements

The working electrode was prepared by 85 wt% of the active material (OMC), 10 wt% of conducting agent (carbon black), and 5 wt% of binder (polyvinylidene difluoride, PVDF). This mixture was pressed onto the glassy carbon electrode (Aida Hengsheng Technology co. td, Tianjin, China) and then dried at 60 °C. The electrolyte used was 3 M KOH aqueous solution. The capacitive performance of the sample was tested on the CHI660 electrochemical workstation (CHI, USA) with cyclic voltammetry and chronopotentiometry functions using three-electrode system (a saturated calomel electrode (SCE) as the reference electrode, a Pt electrode as the counter electrode). Experiments were carried out at room temperature.

3. RESULTS AND DISCUSSION

The crystal phase of the sample was analyzed by X-ray diffraction (XRD). The powder XRD pattern of the sample in our experiment is shown in Fig.1. The characteristic peaks are at $2\theta = 22.9^\circ$ and 43.1° corresponding to amorphous carbon [corresponding to (002) and (100) reflection,

respectively]. The broad diffraction peaks demonstrate that OMC exists as amorphous phase with very small size [12].

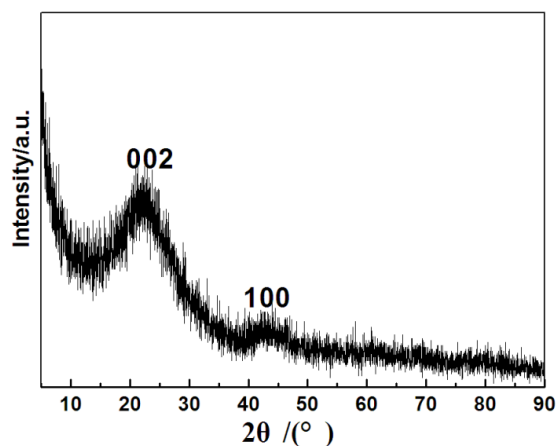


Figure 1. XRD pattern of the synthesized well-ordered mesoporous carbon

The broad diffraction peaks demonstrate that Com exists as amorphism phase with very small size. It means that we obtain the finer size and amorphous state of electrode materials to provide a large amount of superficial electroactive species to participate in faradic redox reaction.

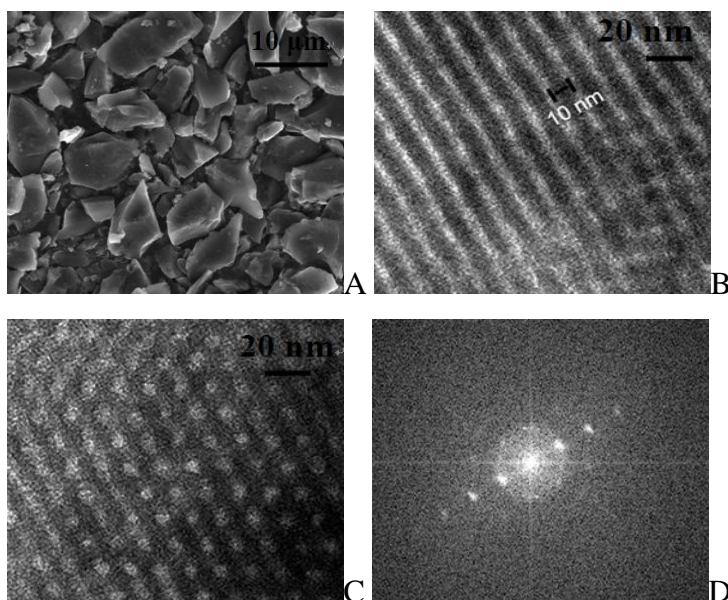


Figure 2. SEM image (A) and TEM images (B: top view, C: cross-section, D: fourier transformation of TEM image) of the OMC

To further investigate the OMC particles, SEM image was adopted. Fig.2 shows the SEM and TEM image of OMC particles. As Fig 2A and Fig.2B shown, OMC is built by rows of well-ordered carbon walls accumulated with small-sized carbon nanoparticles. The width of the carbon wall is about

10 nm. Fig.2C shows the cross-section of the well-ordered carbon walls presenting a mesoporous structure. The well-ordered mesoporous structure provides a large surface area of the OMC, and this configuration is beneficial to diffusing the redox couple in the electrolyte.

CP curves at different current densities are shown in Fig.3. The characteristic of charging and discharging curves is good, which means the OMC particles with excellent electrochemical capability and the process is reversible. Fig.3 shows the charging/discharging voltage profiles at 5, 8 and 10mA, and the Coulombic efficiency is nearly 100% for each cycle. The characteristics of charging/discharging curves are almost ideal, which means that the OMC electrodes have excellent electrochemical capability.

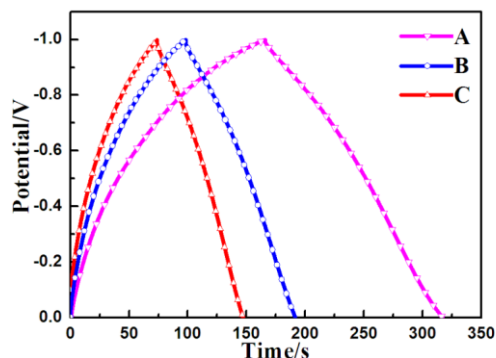


Figure 3. CP curves of OMC at different current(A=5, B=8, C=10mA)

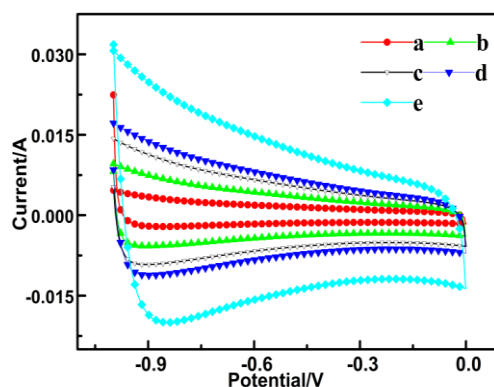


Figure 4. Cyclic voltammograms curves of the OMC at different scan rates (a=2; b=5; c=8; d=10; e=20 mV/s)

Fig.4 shows the CV curves of the OMC electrode at different scan rates (a=2; b=5; c=8; d=10; e=20 mV/s). The potential span is from -1.0V to 0.0 V (vs.SCE) in 3 M KOH aqueous solution. We can see that the CV curves have no peaks. From the CV curves at scan rates of 2, 5, 8, 10 and 20mV/s, the corresponding specific capacitances are 150, 120, 110, 100 and 90F/g respectively. The results suggest that these active OMC have relatively higher capacitance and better capacitance retention than other reported results [10-12]. Therefore, at a slow scan rate, full utilization of the electroactive surface of OMC particles enhances the specific capacitance.

Electrochemical impedance spectroscopy (EIS), a powerful technique for investigation of the capacitive behavior was used to evaluate the activity of the OMC. The electrochemical behavior of our experiment for EIS testing is based on a three-electrode system which includes counter electrodes, reference electrode, and working electrode. Impedance spectra for the OMC electrodes are presented in Fig.5. The results show it has lower impedance than others [7, 11, 12].

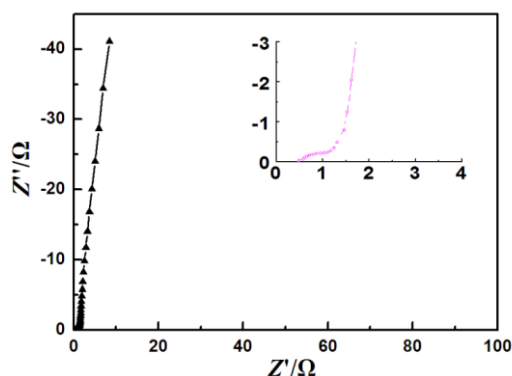


Figure 5. Impedance characteristic curve of OMC

The plots exhibit two distinct traits: a semicircle in the high frequency range and a sloped line in the low frequency range. The magnitude of the resistance can be estimated from the curvature of the high frequency loop; whereas the diffusion is characterized by the linear area at lower frequency is caused by the different dynamic diffusion among the carbon materials. The semicircle diameter is large, demonstrating the higher impedance, which leads to the poor ion transport behavior. This is in accordance to the capacitance retention ratio results.

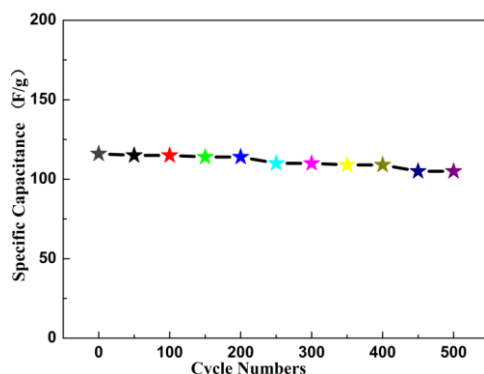


Figure 6. Cycle-life performance of the OMC electrode samples at 5 mA

It is also very important for electrode materials to have good specific capacitance retention. The supercapacitors should work steadily and safely, which requires the capacitance of electrode materials to change as little as possible. Fig. 6 shows the profile of the specific capacitance versus charge/discharge cycle numbers at 5 mA. At the beginning, the specific capacitance of OMC electrode

is 120 F/g. At the end of 500 cycles, the specific capacitance of OMC electrode is 110 F/g which indicates that 91.7 % of their initial capacitance can be retained. The results suggest that these OMC particles have relatively higher capacitance and more excellent capacitive retention than other articles [2, 7, 11].

4. CONCLUSIONS

In summary, we successfully synthesized well-ordered mesoporous carbon using the F127 as raw material. The results showed that: the orderly rules of the OMC pore wall width of 10 nm. Constant current charge and discharge, cyclic voltammetry and impedance spectra showed that this electrode materials with good electrochemical performance, good reversibility. In addition, at a current density of 700 mA/g, ordered mesoporous carbon has capacitance retention rate of 90.5% after 500 cycles test.

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